Geographically Based Investigation of Prostate Cancer Mortality in Four U.S. Northern Plain States

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Background: Historically, prostate cancer mortality rates have been elevated in the U.S. Northern Plains states. The purpose of this study was to investigate possible contributing factors, especially whether there was any association with crop patterns.

Methods: Prostate cancer mortality rates (1950–2000) in four northern plains states (MN, MT, ND, and SD) were compared to rates for 46 other U.S. states. Within the four states, county rates in urban, less urban, and rural areas also were compared. For additional analysis, urban counties and counties with <10% of county area in crops were excluded. The average percent of county area in total cropland 1930–1950 and 1954–1974 was estimated. Using Poisson regression, we investigated whether the average percentage of county area in total cropland, 1930–1950 and 1954–1974, was associated with prostate cancer mortality rates, 1975–2000, respectively. Poisson regression analyses were also used to evaluate associations between rates and major crops, which included spring and durum wheat, winter wheat, corn, and other crops. Population centroids of the Census 2000 block groups were used to estimate the percentage of males aged 35 and older residing in close proximity to small grains crops.

Results: Mortality rates were higher in rural compared to urban counties in 1950–2000 (rate ratio [RR]=1.032; 95% CI=1.001–1.063). Rates in 1950–1974 were significantly associated with production of corn and other crops in 1930–1950 (corn: RR per 10% increase=1.033, 95% CI=1.012–1.054; other crops: RR=1.042, 95% CI=1.021–1.063). Mortality rates in 1975–2000 were significantly associated with spring and durum wheat production in 1954–1974 (RR per 10% increase=1.042, 95% CI=1.017–1.067). Prostate cancer mortality rates increased as the percentage of population living within 500 m of small grains crops increased.

Conclusions: Epidemiologic studies to evaluate agricultural practices are warranted to further evaluate the observed associations.
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Introduction

The *Atlas of Cancer Mortality in the United States*[1] maps cancer mortality rates by county for two time periods: 1950–1969 and 1970–1994, both of which showed elevated prostate cancer mortality rates in the Northern Plains region. Using a spatial scan statistic, Jemal et al.[2] found a primary cluster of prostate cancer mortality among white men in the northwestern quadrant of the country, which included the states of Montana, North Dakota, and Minnesota. These states and South Dakota produce most of the country's spring and durum wheat, which requires intensive application of herbicides. A study by Schreinemachers[3] investigated cancer mortality during 1980–1989 in agricultural counties of Montana, Minnesota, and North and South Dakota by county wheat production in 1982. Cancer of the prostate was one of several cancer sites associated with higher wheat production (highest tertile of wheat production standardized rate ratio (SRR)=1.24; 95% CI=1.14–1.36).

The objective of the current study was to further evaluate why rates of prostate cancer are higher in these four states by comparing county-level mortality rates across time periods relevant to pesticide use, by comparing rates in urban and rural areas, investigating associations between mortality rates and acreage of crops produced in these states, and the proximity of

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these crops to our study population. The exposure and outcome timeframe of the current study expands upon Schreinemachers study by using 50 years of wheat, corn, and other crop production data and 50 years of prostate cancer mortality data, to carry out a county-level ecologic study.

Methods

Data Sources

County mortality data (1950–2000) from the U.S. National Center for Health Statistics was used to calculate age-adjusted mortality rates (5-year age groups) for white males aged 35 years and older in Minnesota, Montana, North Dakota, South Dakota, and in the rest of the U.S. (46 states). Only white subjects were included because data for nonwhites in the four states were sparse. U.S. Department of Agriculture (USDA) rural–urban continuum codes (RUCC)[4] were used to classify counties according to three population groups: urban counties (RUCC 1–3; metropolitan areas); less urban counties (RUCC 4–7; population ≥2500, not within metropolitan areas); and rural counties (RUCC 8, 9; completely rural or <2500 population). RUCC codes were evaluated for 1974 (first year available), 1983, and 1993. The 1974 codes then were used for further analyses because the RUCC changed little across the three time periods.

Data from the USDA National Agricultural Statistics Service (NASS) agricultural census years 1930, 1935, 1940, 1945, 1950, 1954, 1959, 1964, 1969, 1974, and 1978 was used to calculate the percentage of a county's area that was total cropland. Total cropland was defined as crops harvested plus land on which crops were planted but failed. Land in cover crops, legumes and soil-improvement grasses, cultivated summer fallow, and idle (total) cropland were excluded.

County acreage of wheat, corn, and other crops from the USDA NASS (annual) Agricultural Statistics Data Base[5] were obtained for each Agricultural Census year between 1930 and 1978. Because herbicide use on spring and durum wheat is high (>90% of acreage was treated with herbicides in the 1990s, compared to about 30% of winter wheat),[6] acreage of spring and durum wheat (SDW) was combined, but winter wheat (WW) acreage was analyzed separately. Acreage of corn and other crops (OC) also were evaluated as variables.

A geographic information system (GIS) was used to create data layers of census block group boundaries and population centroids from the 2000 U.S. Census,[7] including the population of males over age 35. A data layer also was created to locate small grain crops (wheat, barley, oats, and rice) from the 1992 National Land Cover Database.[8]

Data Analysis

Poisson regression was used to calculate rate ratios (RR) and 95% CI, adjusted for age in calendar year and 5-year groups. Prostate cancer mortality rates in the four states from 1950–2000 were compared to the rest of the U.S., in 10-year periods (1955–1964, etc.), and across the three RUCC groups. The models included terms representing the interaction between year and state (4 vs 46 states) or RUCC (urban, less urban, or rural), to determine if there was a significant difference in the annual increase of rates for the respective comparisons.

For the analyses of prostate cancer mortality and crop production, counties with <10% of the county area in crops and counties that were urban (RUCC codes 1–3) were excluded. This left 190 (of 262) counties for analysis. Among these counties, the percent of county acreage in crops ranged from 10% to 77% (59,159 to 711,239 acres). Figure 1 presents the counties included in the analyses (solid), those excluded (cross-hatched), and the quintile categories of the county prostate cancer mortality rates.

Spearman's rank correlations across the 11 Agricultural Census years (1930–1978) were high for total cropland acreage (r>0.90), SDW (r>0.83), corn (r>0.95), and OC (r>0.95), indicating that a county's rank remained fairly constant over this time period. Correlations were lower for WW (0.34 to 0.99), likely due to the low acreage (median=411). The average acreage of each commodity over the period 1930–1978, and in earlier (1930–1950) and later (1954–1974) periods, were calculated. Because counties varied greatly in size, the average acreage of each crop type was divided by the county area. Dividing by county farmland acreage or cropland acreage resulted in percentages that were highly correlated with percentages based on the county area, so results are presented only for crops as a percent of the county area.

Tertiles of the percent acreage of each crop were compared to the lowest tertile. In addition, the third tertile was divided at the median. The percent acreage was evaluated as a continuous variable in linear and quadratic models. In all analyses, adjustments were made by 5-year age groups. Although the latency period of prostate cancer is not well-established, it is estimated to be approximately 20–25 years.[9,10] Therefore, a 20-year lag was incorporated by evaluating crop production in the earlier and later periods in relation to mortality in 1950–1974 and 1975–2000, respectively.

Besides evaluating crops individually, all crop types were included in the same model (additive model) to evaluate the effects of increasing the acreage of one crop, while keeping other crops constant.[8] The substitution effect[11] of replacing SDW with corn was evaluated by including one variable for the combined acreage in either crop (SDWC=SDW+corn) and one variable for SDW. Because the combined acreage SDWC is held fixed, an increase in SDW is offset by decreasing an equal amount of corn. The remaining crop types WW and OC were included in the model as adjustments.

For the 190 counties in the crop production analyses, a GIS was used to estimate the proximity of census block group (CBG) centroids to small grain crops. Circular buffers were created with a radius of 250, 500, 750, and 1000 m around each CBG population centroid, and whether the buffers intersected small grain crops was determined. Buffer radii were chosen to represent a range of distances of primary pesticide drift from ground and aerial spraying. For each county, the percent of males aged 35 and older living in CBGs with grain crops within each buffer distance of their respective population centroids were calculated. Poisson regression was used to evaluate the association between average county-level prostate cancer mortality rates (1975–2000) and the percent of the county population living proximate to grain crops.

To evaluate whether there was spatial auto-correlation among the prostate cancer mortality rates, both before and after adjustment for the agricultural variables, Tango's maximized excess

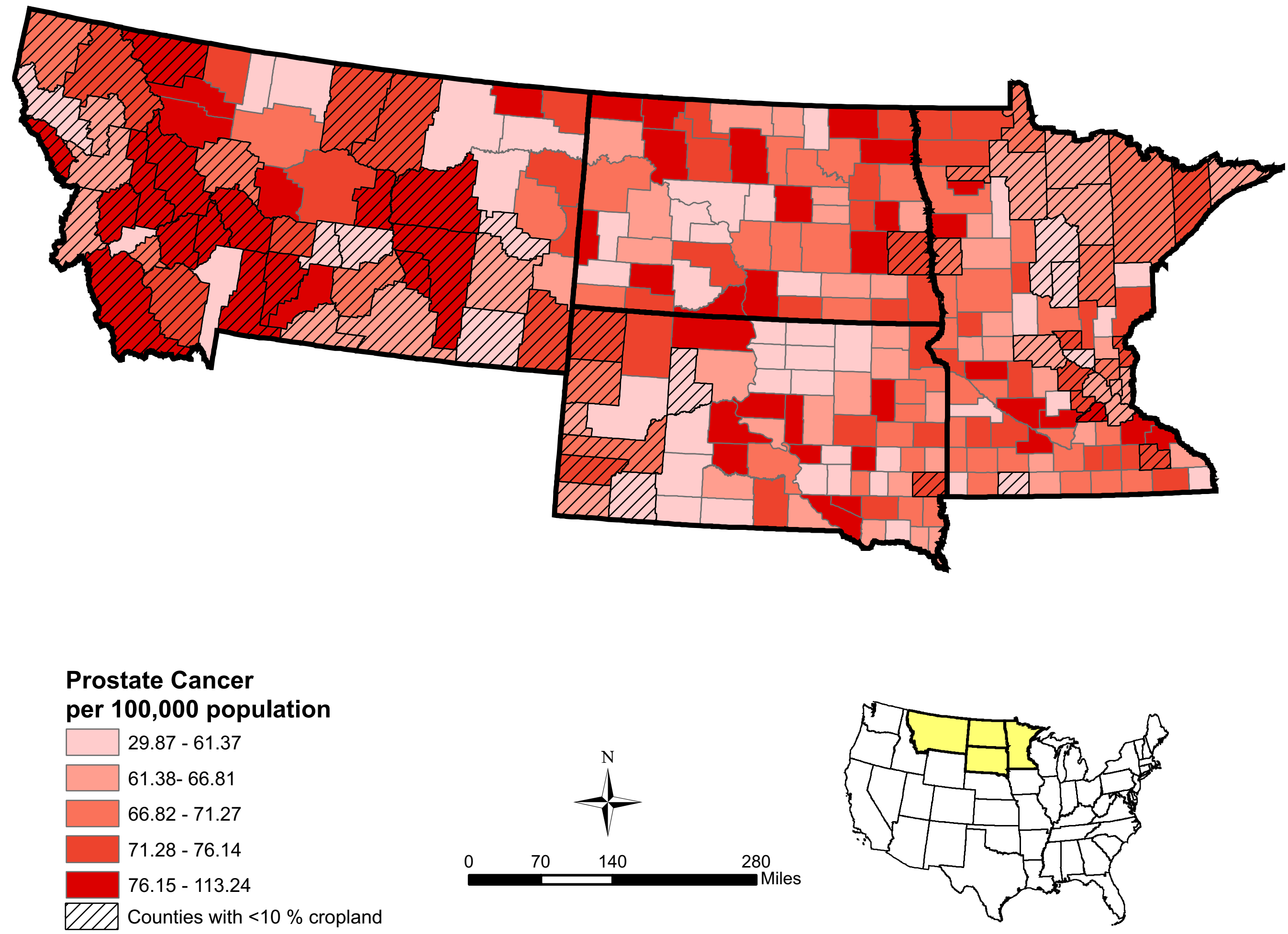

Figure 1. Map of prostate cancer mortality (1950–2000) 5-year, age-adjusted rates per 100,000 population (aged 35+).

events test (MEET)[12] was used, which has been shown to be robust in detecting spatial auto-correlation in count data.[13,14] County population centroids from the 2000 U.S. Census Bureau were used to define the geographic coordinates used by this test. Significant spatial auto-correlation in the data was not detected, either before or after adjustment for agricultural variables. Therefore, a spatial term was not included in the Poisson regression models for total cropland, SDW, WW, corn, and OC.

Results

From 1950–2000, prostate cancer mortality rates in the four northern plains states were 12% higher than rates in the other 46 U.S. states (RR=1.12; $p<0.001$) (Table 1). Over this period, prostate cancer mortality increased 0.32% per year for the four states, whereas the increase was 0.23% per year for the 46 other U.S. states, a statistically significant difference of 0.09% per year. Rates for the four states and the other 46 states peaked during 1985–1994 (Figure 2). Rates were significantly higher in the four states in each 10-year time period from 1955–1994 (data not shown). In 1950, there were 447 prostate cancer deaths in the four states combined, and the population of white males over 35 years of age

Table 1. Prostate cancer mortality RR and 95% CI for annual percent increases in rates for 4 northern plains states compared with 46 other U.S. states and for urban, less urban and rural counties in the 4 states (1950–2000)

Comparison		95% CI	*p*-value
Comparison of rates, RR			
4 versus 46 states	1.118	(1.107–1.119)	<0.001
Smaller urban versus urban	1.017	(0.994–1.004)	0.16
Rural versus urban	1.032	(1.001–1.063)	0.04
Percent increase in rates, annual % increase			
46 states	0.23		
4 states	0.32		
4 versus 46 states: difference in annual % increase	0.09	(0.02–0.17)	0.02
Urban counties	0.30		
Less urban counties	0.30		
Rural counties	0.39		
Less urban versus urban: difference in annual % increase	0.00	(-0.17–0.16)	0.99
Rural versus urban: difference in annual % increase	0.09	(-0.12–0.30)	0.41

RR, rate ratios; 95% CI, 95% confidence interval.

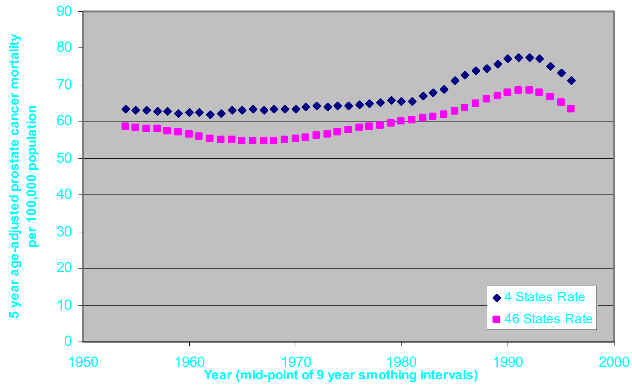

Figure 2. Prostate cancer mortality rates (5-year, age-adjusted, smoothed using 9-year moving averages) from 1950–2000: four northern plains states versus 46 other U.S. states.

was 1,048,921. By 2000, the number of prostate cancer deaths had increased to 880 of a population of 1,682,316.

Over the 50-year period, prostate cancer mortality rates in less urban counties were not significantly different than rates in urban counties; whereas rates in rural counties were 3% higher than urban counties (RR=1.032; p =0.04), (Table 1) (Figure 3). The annual increase in mortality was 0.30% for urban counties, 0.30% for less urban counties, and 0.39% for rural counties. The 0.09% difference between rural and urban counties was not statistically significant (p =0.41).

The results for total cropland acreage and prostate cancer mortality are presented in Table 2. Overall, no increase in prostate cancer mortality rates was observed in 1950–2000 with increasing tertiles of the percentage of the county area as total cropland. Analyzed as a continuous variable, there was a nonsignificant increased RR with increasing total cropland (0.6% increase for each 10% unit increase in total cropland). Including a quadratic term in the model did not result in a statistically significant better model fit (p =0.07; data not shown). However, the two highest total cropland categories in the earlier period were associated with significantly increased mortality rates (1950–1974). Analyzed as a continuous variable, there was a 2.4% increased RR for each 10% unit increase in total cropland (p <0.001). Mortality rates in 1975–2000 were not associated with the county area in total cropland when analyzed either as a categorical or a continuous variable.

Overall, no association was found between the average acreage of SDW, WW, or corn as a percent of the county area and prostate cancer mortality in 1950–2000 (Table 3). For OC, however, there was a significantly increased mortality rate in the highest category of exposure (RR=1.047; 95% CI=1.001–1.094). For the earlier period, no association was found between SDW or WW and prostate cancer mortality (1950–1974). However, for corn and OC there were statistically significant increasing rates in the two highest categories and increasing rates for each 10% unit increase in county area in each commodity (corn: RR=1.033; 95% CI=1.012–1.054; OC: RR=1.042; 95% CI=1.021–1.063). For the later period, no association was found between WW or OC and mortality in 1975–2000. For SDW there were statistically significant increased rates in the highest category (RR=1.1000; 95% CI=1.037–1.167) and a significant increase for each 10% unit increase in the county area in SDW (RR=1.042; 95% CI=1.017–1.067). In this later period, there were statistically significant decreased rates associated with increasing corn production (for each 10% unit increase: RR=0.982; 95% CI=0.971–0.994).

Results for the additive model with all crop types and for the substitution effect model are presented in Table 4. Results with all crop types in the models were similar to that for the individual crop types. For the earlier period, there was a 32.8% increase in prostate cancer mortality (1950–1974) for each 10% unit increase in OC (RR=1.328; 95% CI=1.024–1.722). For the later crop production period, there were non-significant, elevated rates in 1975–2000 for each 10% unit increase in SDW (RR=1.239; 95% CI=0.908–1.691). Overall, the substitution effect between SDW and corn indicated a 25% increase in prostate cancer mortality in 1950–2000 for every 10% increase in SDW and concomitant decrease in corn. There was no statistically significant substitution effect for the early period. In the later period there was a significant 55% increase in mortality (1975–2000) for every 10% increase in SDW acreage (and concomitant decrease in corn).

Results for the analysis of the percent county male population aged 35 or over living within 500 m of small grain crops are presented in Table 5. As the percentage of this population increased, so did the rates for prostate cancer mortality. For example, in counties where greater than 67.6% of the population lived within 500 m of small grains crops, prostate cancer mortality was 9% higher than in counties where none of the population lived within 500 m of small grain

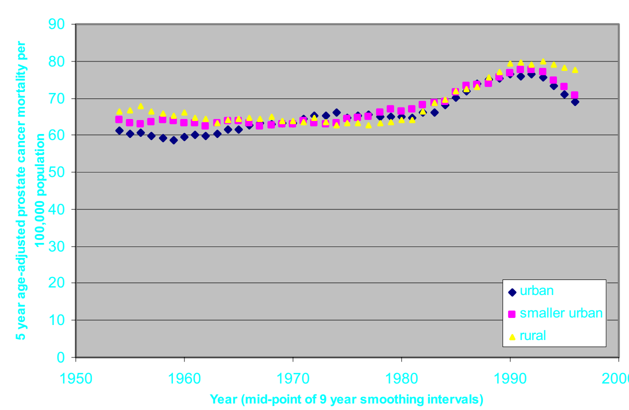

Figure 3. Prostate cancer mortality rates (5-year, age-adjusted, smoothed using 9-year moving averages) from 1950–2000: rural counties, smaller urban counties, urban counties.

Table 2. Prostate cancer mortality by county area in cropland in four U.S. northern plains states

Percent of county area in cropland[a]	Whole period : 1930–1978 cropland versus 1950–2000 prostate cancer mortality			1930–1950 cropland versus 1950–1974 prostate cancer mortality			1954–1974 cropland versus 1975–2000 prostate cancer mortality		
	RR	95% CI	p-value	RR	95% CI	p-value	RR	95% CI	p-value
10–<40	1.000			1.000			1.000		
40–60	1.012	(0.974–1.052)	0.54	1.063	(0.993–1.139)	0.080	0.983	(0.930–1.038)	0.53
60–<67	1.017	(0.972–1.064)	0.47	1.091	(1.013–1.175)	0.020	0.994	(0.930–1.063)	0.86
≥67	1.020	(0.979–1.063	0.35	1.130	(1.052–1.214)	0.001	0.981	(0.921–1.045)	0.56
Continuous[b]	1.006	(0.998–1.014)	0.15	1.024	(1.012–1.037)	<0.001	0.995	(0.983–1.007)	0.42

[a]Tertiles of percent of county area in cropland, excluding counties for which <10% of county area is cropland; third tertile was split at the median.
[b]Estimate for each 10% increase in crop coverage.
RR, rate ratio; 95% CI, 95% confidence interval.

crops (RR=1.09; 95% CI=1.02–1.17). Findings for other buffer sizes (250, 750, and 1000 m) were similar (not shown).

Discussion

Mortality rates for prostate cancer in white males aged 35 or older were significantly higher in four northern plains states compared to the other 46 U.S. states over the period 1950–2000. Rural counties had significantly increased mortality rates compared to urban counties, whereas mortality rates were not statistically elevated in smaller urban counties. A significant association was observed between the percent of the county area in corn and other crops and prostate cancer mortality in 1950–1974. Mortality in 1975–2000 was significantly associated only with SDW, and the substitution effect of growing SDW, rather than corn, was statistically signif-

Table 3. Prostate cancer mortality associated with county area in spring and durum wheat,[a] winter wheat, corn, and other crops

Percent of county area in cropland[a]	Whole period: 1930–1978 cropland versus 1950–2000 prostate cancer mortality			1930–1950 wheat versus 1950–1974 prostate cancer mortality			1954–1974 wheat versus 1975–2000 prostate cancer mortality		
	RR	95% CI	p-value	RR	95% CI	p-value	RR	95% CI	p-value
Spring and durum wheat, combined									
0–<2.7	1.000			1.000			1.000		
2.7–<11	1.021	0.986–1.057	0.25	1.030	0.975–1.088	0.29	1.011	0.996–1.059	0.63
11–<19	1.018	0.971–1.066	0.47	1.016	0.947–1.090	0.66	1.029	0.970–1.092	0.34
≥19	1.029	0.987–1.073	0.18	0.989	0.926–1.058	0.76	1.100	1.037–1.167	0.002
Continuous[b]	1.016	0.999–1.034	0.07	0.993	0.966–1.020	0.66	1.042	1.017–1.067	0.001
Winter wheat[c]									
0–<0.1	1.000			1.000			1.000		
≥0.1	0.993	0.964–1.022	0.64	0.976	0.928–1.026	0.34	1.000	0.958–1.044	0.99
Continuous[b]	1.020	0.901–1.156	0.71	0.888	0.694–1.136	0.36	1.079	0.956–1.217	0.22
Corn									
0	1.000			1.000			1.000		
>0–<11.5	0.949	0.913–0.987	0.01	1.012	0.951–1.078	0.7	0.922	0.877–0.969	0.001
11.5–<23	0.985	0.944–1.027	0.48	1.1	1.032–1.174	0.004	0.894	0.878–0.955	0.001
≥23	0.976	0.938–1.015	0.22	1.08	1.012–1.152	0.02	0.911	0.869–0.955	<0.001
Continuous[b]	0.996	0.984–1.008	0.5	1.033	1.012–1.054	0.002	0.982	0.971–0.994	0.003
Crops other than spring, durum, winter wheat, or corn									
0–<21	1			1			1		
21–<36	0.991	0.951–1.033	0.67	1.036	0.969–1.107	0.3	0.947	0.901–0.995	0.03
36–<39	1.021	0.977–1.067	0.35	1.103	1.014–1.199	0.02	0.966	0.910–1.025	0.25
≥39	1.047	1.001–1.094	0.04	1.119	1.061–1.205	<0.001	0.966	0.090–1.025	0.25
Continuous[b]	1.013	0.999–1.027	0.08	1.042	1.021–1.063	<0.001	0.991	0.976–1.008	0.23

[a]Tertiles of percent of county area in specific crops, excluding counties for which <10% of county area is cropland; third tertile was split at the median.
[b]The percent of county area of WW was categorized at the median.
[c]Estimate for each 10% unit increase.
RR, rate ratio; 95% CI, 95% confidence interval.

Table 4. Percent of county area in cropland and specific crops, additive and substitution models

	1930–1978 crop versus 1950–2000 prostate cancer mortality		1930–1950 crop versus 1950–1974 prostate cancer mortality		1954–1974 crop versus 1975–2000 prostate cancer mortality	
	RR*	**95% CI**	**RR**	**95% CI**	**RR**	**95% CI**
Cropland	1.060	(0.979–1.147)	1.287	(1.130–1.466)	0.950	(0.839–1.076)
Additive effects						
Spring and durum wheat	1.104	(0.866–1.410)	1.053	(0.723–1.536)	1.239	(0.908–1.691)
Winter wheat	3.567	(0.880–14.459)	0.643	(0.045–9.198)	2.094	(0.551–7.957)
Corn	0.881	(0.723–1.073)	1.169	(0.836–1.636)	0.886	(0.735–1.067)
Other crops	1.291	(1.1070–1.558)	1.328	(1.024–1.722)	1.035	(0.826–1.297)
Substitution effects						
Spring and durum versus corn	1.254	(1.042–1.510)	0.931	(0.681–1.272)	1.549	(1.214–1.975)

Estimate for each 10% increase in county area in crop.
RR, rate ratio; 95% CI, 95% confidence interval.

icant. In addition, as the proportion of white males aged 35 and older living within 500 m of small grains crops increased in a county, average prostate cancer mortality rates increased significantly for the period 1975–2000.

These results support and extend the findings of Jemal et al.[2] that prostate cancer mortality rates are elevated in the Northern Plains region in 1970–1989. The ecologic study of Schreinemachers[3] found significantly increased mortality from prostate cancer in 1980–1989 in counties in the highest tertiles of total wheat acreage. In the current study, elevated mortality rates in 1975–2000 were observed among counties with a higher percentage of county area in SDW production; however, no association was found between prostate cancer morality and wheat production in an earlier time period (1950–1974). Instead, mortality rates in the earlier period were significantly associated with production of corn and OC. Thus, the results in the current study suggest that factors associated with production of corn, OC, as well as SDW may explain the elevated mortality from prostate cancer in the four states.

The association between proximity to small grains crops and prostate cancer mortality could be attributable to occupation in farming (i.e., farmers live closer to crops).[15] Distances were chosen based on primary drift, however, so environmental exposures to pesticides may also be greater for those in close proximity to crops.[15]

Table 5. Percent of population living within 500 m of small grains crops

Percent of population living within 500 meters of small grains crops	Population centroids data versus 1975–2000 prostate cancer mortality	
	RR	**95%CI**
0	1.00	
>0–24.6	1.04	0.99–1.102
>24.6–67.6	1.07	1.01–1.13
>67.6–100	1.09	1.02–1.17
Linear model	1.10	1.03–1.18

Numerous occupational studies have found increased prostate cancer incidence and mortality among farmers[16–30] whereas a few studies have not.[31–33] A meta-analysis by Blair et al.[34] concluded that farmers had significantly elevated rates of prostate cancer (OR=1.08, 95% CI=1.06–1.11). Agricultural chemical exposures, viruses, or other factors may be responsible for increased rates but the etiologic factors that may contribute to this excess among farmers have not been identified.[16]

If specific agricultural pesticides are risk factors for prostate cancer, changes in pesticide use over time may result in changes in prostate cancer incidence and mortality in agricultural areas. In general, a limited number of pesticides were applied to wheat, corn and other field crops before the late 1940s.[35] Nationwide, the percent of wheat acres treated with herbicides increased from 23% in 1964 to 42% in 1982.[6] Throughout this period, the major herbicides applied to wheat were the chlorophenoxy acid herbicides, 2,4-D and MCPA, and the benzoic acid, dicamba.[35] Insecticide use on wheat was generally low.[36,37] The USDA pesticide use surveys before the 1990s did not track pesticide use separately for spring, durum, and winter wheat. Based on data from the 1990s, 90% to 95% of spring and durum wheat is treated with herbicides compared to only 30% of winter wheat. Nationwide, the percent of corn acres treated with herbicides increased from 43% in 1964 to 96% in 1992, with the major increase occurring in the 1960s and 1970s. Atrazine and 2,4-D were the major herbicides applied in 1964, whereas by 1992, atrazine, metolachlor, alachlor, and cyanazine were the major herbicides.[35] Since the 1960s, about 30% to 40% of corn acres have been treated with insecticides. Aldrin, an organochlorine insecticide, was used most frequently in the 1960s and early 1970s, but use was prohibited after 1974 in the U.S. Carbofuran, a carbamate insecticide replaced aldrin as the major corn insecticide in the late 1970s to early 1980s.

A limited number of occupational studies have evaluated prostate cancer risk in relation to use of specific agricultural exposures, primarily focusing on pesticides. In the Agricultural Health Study, a cohort of pesticide applicators in Iowa and North Carolina, the exposure metric, lifetime days application of alachlor and of atrazine, was not associated with prostate cancer risk. Another study[38] in the same cohort found significantly increased risk of prostate cancer with use of chlorinated pesticides among applicators over 50 years of age and use of methyl bromide (a fumigant used on stored grain crops, such as wheat). Agent Orange (a 1:1 ratio of 2,4-dichlorophenoxy acetic acid (2,4-D) and 2,4,5-trichlorophenoxy acetic acid (2,4,5,-T)), which was banned in the U.S. in 1970 was found to be associated with prostate cancer in two recent studies,[39,40] however, this association could be due to the contamination of the chemical with dioxin. Additional analytic epidemiologic studies to evaluate prostate cancer in relation to pesticides commonly used in the four states will be informative.

Strengths of the current study include the use of multiple years of crop production and mortality data, which allowed for the evaluation of mortality over time and for the incorporation of a lag period between the period of crop production and mortality. Additionally, the wheat varieties were evaluated separately, as well as corn and other crops. Use of a GIS allowed estimates of the proximity of the population to crop production.

Limitations of this study include those inherent to the ecologic study design that precludes a causal interpretation for associations. The current study comprised only white males, due to sparse data for other racial groups. Because mortality data were used, there could be differences in access to care between rural and more urban areas that could account for some of the increased mortality from prostate cancer in rural areas. Only a small portion of the study period included the 1990s, the era during which prostate specific antigen (PSA) screening resulted in an increase in prostate cancer diagnoses and a subsequent increase in incidence and mortality rates. Therefore, PSA screening should not affect the results substantially. Additionally, when we investigated rates among the rural populations for other cancers (i.e., breast, colon) where access to health care may affect mortality rates, we did not find higher rates compared with those in non-rural areas. We also looked at rates for all cancers combined and concluded that the effect of elevated mortality for prostate cancer in rural counties is not due to higher mortality for all cancers in general among rural dwellers.

An additional potential limitation of the study might be whether the population and crop distribution data are representative. The Tango's MEET analysis and the GIS-based proximity analysis used 2000 centroids. A composite of 1992–1994 satellite imagery (the 1992 USGS National Land Cover Database) was used to identify the location of small grain crop production in the proximity analysis.

Conclusion

The study results suggest that some aspect of rural life or agricultural crop production increases prostate cancer mortality in these states. Changing patterns of agricultural pesticide use may explain some of the associations with crop production that we observed. Analytic epidemiologic studies of prostate cancer to evaluate specific agricultural practices and other factors in our study area are warranted.

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